At a time when the United States is reassessing its support of the International Atomic Energy Agency, it is important to examine the relationship between nuclear power and the spread of nuclear weapons. Following is the first of two articles; the second will appear in the February *Bulletin*.

JOHN P. HOLDREN

Nuclear power and nuclear weapons: the connection is dangerous

In the past few years, blue-ribbon groups in several countries have studied and reported on the liabilities and benefits of nuclear power as an energy source, and nearly all of them have viewed with alarm the link between nuclear power and the spread of nuclear weapons capability. For example, the 1977 report of the Nuclear Energy Policy Study Group of the Ford Foundation, whose authors included an impressive array of senior U.S. defense analysts, stated:

"The consequence of nuclear power that dominates all others is the attendant increase in the number of countries that will have access to the materials and technology for nuclear weapons."[1]

The widely quoted report of the United Kingdom's Royal Commission on Nuclear Power and the Environment, said:

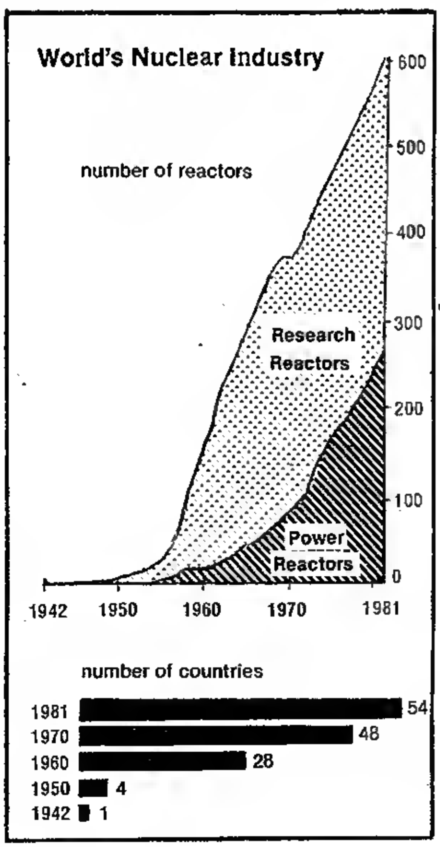
"The spread of nuclear power will inevitably facilitate the spread of the ability to make nuclear weapons and, we fear, the construction of these weapons."[2]

And the Australian national inquiry into whether that country should continue to mine and export uranium for nuclear power generation in other countries—the Ranger Report—concluded:

"The most serious danger in our view is that of proliferation of nuclear weapons."[3]

None of these eminent groups could reasonably be labeled "anti-nuclear." They tried to characterize fairly the liabilities as well as the benefits of nuclear power, so that those making decisions about this energy source would be able to do so on the basis of complete information.

This is my goal as well. I do not claim that nuclear power's "weapons connection" manifestly renders its use intolerable. I simply contend that a realistic appraisal of the weapons liability must be included—along with the best information about the other costs and benefits of nuclear power and of its alternatives—in any sensible evaluation of energy strategies.



Acquiring nuclear weapons: motivations and barriers. Some analysts try to dispose of the weapons connection by arguing that weapons proliferation is mainly (or even solely) a political problem.[4] Their reasoning goes something like this: The motivation for acquiring nuclear weapons is political; the technology for acquiring nuclear weapons cannot be controlled in any case; therefore, the only practical preventive actions are political ones that reduce the motivation.

The point about motivation is substantially correct, but the rest of the argument ignores the nonpolitical—technical and economic—barriers to acquisition of nuclear weapons, as well as implicitly oversimplifying the political ones. It dismisses a wide range of options by which the spread of weapons-relevant technology could be slowed, as if anything short of stopping it were not worthwhile. It fails to apply to the political measures it endorses the same criterion of perfection implicit in its rejection of technological measures. And it entirely begs the question of the costs of failure: In energy decision-making, what weight should be given to the possibility that the best attainable combination of political and technological measures will not prevent *some* acceleration of the spread of nuclear weapons?

A less simplistic approach must recognize the *interaction* of motivations and barriers to weapons acquisition, and must try to understand how the presence of commercial nuclear power affects that interaction. The key relations are as follows: The rate of increase in the number of nuclear-

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armed nations depends on the strength of the motivations for nuclear-weapons acquisition, which are mainly political, *relative* to the height of the barriers, which are political, economic and technical. If a country is strongly motivated to acquire nuclear weapons, it will succeed eventually in doing so, with or without the help of commercial nuclear power. But in the presence of nuclear power, even weaker motivations suffice to justify a decision for nuclear weapons, because nuclear power unavoidably lowers the barriers.

Technology. The main technical barriers to acquisition of fission weapons do not include the "secret" of how to design such a bomb. That information must be presumed to be readily available to any and every interested nation.[5] (Fusion bombs are a different matter, which I shall not discuss here.[6]) Rather, the main technical barriers are a weapon program's requirements for a sizable cadre of highly trained specialists and for a source of fissionable raw material plus the facilities for converting it to weapons-usable form.

A commercial nuclear power program lowers these barriers in three ways:

- Even in its formative stages, the program assembles people having the same skills needed for a weapons program and melds them into a working unit.
- A nuclear power program cannot avoid solving the problem of fissionable material, typically on a small scale at the research reactor stage that precedes commercial operations, and necessarily on a large scale at the commercial stage.
- Such programs often provide directly the means for converting the raw fuel into weapons-usable material, and even if a country refrains at first from acquiring this capability, having both raw material and personnel simplifies a later decision to do so.

The seriousness of this third aspect of the problem is sometimes disparaged with the contention that the plutonium produced in commercial reactor operations is unsuitable for weapons use. The idea is that the high content of even-numbered isotopes in plutonium from reactors operated to maximize power production will impose unacceptable penalties in yield and reliability of nuclear bombs made from it. But this notion is doubly flawed. First, with suitably sophisticated weapons design, the performance penalty can be made very small.[7] And second, one commercial reactor type used in several countries—the continuously refuelable CANDU—provides the alternative of minimizing the content of the troublesome plutonium isotopes with little economic penalty.[8]

Economics. The economic barrier is, of course, the high cost of building and running facilities dedicated to weapons production. The economic issue, however, is often misleadingly formulated: It is cheaper to build and run a plutonium-production reactor or centrifuge plant for uranium enrichment than to build and run a commercial nuclear power program.[9] This is a correct answer to the wrong question. The right question is: What is the *marginal* cost of developing a weapons production program of any desired size with the help of a commercial nuclear power program already in place, versus developing such a program with personnel and facilities dedicated exclusively to weaponry? Since much of the cost of the nuclear power program can be recovered from the sale of electricity, the answer is that the marginal cost of adapting a nuclear power program to produce bombs as well as electricity is less than the cost of building from scratch an equivalent weapons capability in facilities totally dedicated to that purpose. The word "equivalent" is important here: The smaller plutonium-production reactors, whose modest cost is often touted, produce only a few bombs' worth of plutonium per year; a single large power reactor can produce 20 to 50.[10]

An even more specific confirmation of the economic advantage of the commercial-power route to bombs is available in a most distressing form: the admission by the U.S. government, in late 1981, that it is considering turning to commercial-reactor fuel as the source of plutonium for a new round of nuclear warheads.[11] Would the United States even consider paying the political costs of such a move unless its economic attractiveness were compelling?

Politics. The political barriers to the acquisition of nuclear weapons are possibly the most important ones, even as political factors dominate the motivations.[12] A country may desire nuclear weapons to counter threats to its own national security, to increase its capacity to achieve by force political objectives outside its boundaries, or simply to increase its regional or global prestige and influence. The main political barriers opposing these motivations are:

- concern that possession of nuclear weapons may increase a country's chances of being attacked with such weapons;
- the international "norm" against acquisition of nuclear weapons, including but not limited to the Non-Proliferation Treaty;
- the possibility of divisive and even government-threatening internal dissent over acquiring nuclear weapons;
- the possibility that a decision to acquire them will stimulate increased external sanctions and countermeasures.

Not all of these political barriers are lowered by the existence of an indigenous nuclear power program, but

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some are. Most importantly, a power program provides a legitimating cover for nuclear activities which would otherwise be unambiguously weapons-oriented. A country embarking on a nuclear weapons program without such cover is apt to be discovered and exposed. But if a nuclear power program is in place, the country has a benign rationale for the presence of nuclear-trained personnel, for acquiring fissile materials, and for building facilities that make it easy to transform these materials into weapons-usable forms.

In general, a country that has acquired nuclear weapons must eventually make this fact known if it is to obtain the benefits of that acquisition.[13] Why, then, would having the cover of a nuclear power program matter? Mainly because a country embarked on a weapons program is most vulnerable to both internal dissent and external countermeasures in the interval between making the decision and actually possessing the weapons. A nuclear power program makes it possible to mask weapons intentions through all the early steps and perhaps even into the stockpiling phase.

Perhaps worse, a nuclear power program established with wholly benign intent may become the vehicle for a rapid transition to nuclear-weapons status when internal political circumstances or external incentives change. In this respect, certain components of nuclear power programs—notably enrichment plants, reprocessing plants, and stockpiles of separated plutonium—must be considered "attractive nuisances" of a most dangerous kind; by making it so easy, they may constitute an irresistible temptation to produce nuclear weapons under provocation insufficient to motivate undertaking a weapons program from scratch. Victor Gilinsky, a member of the U.S. Nuclear Regulatory Commission and long-time analyst of the "weapons connection" has concluded for the foregoing reasons that commercial nuclear power provides "the quickest, cheapest, and least risky route to nuclear weapons."[14]

History of power-related proliferation. Part of the conventional wisdom of the proliferation literature is that none of the countries known to have acquired nuclear weapons to date has used the power reactor route.[15] This is correct, but misleading, because it fosters an artificial distinction between nuclear power *reactors* and nuclear power *technology* as a whole—including enrichment and reprocessing technology, trained personnel, and infrastructure. The pertinent question is whether the development and/or transfer of nuclear power technology has contributed to the spread of nuclear weapons.

For the first three nuclear-weapons states—the United States, the Soviet Union and the United Kingdom—civilian nuclear technology was an offshoot of military technology, not vice versa. When they began their weapons programs, no civilian nuclear technology existed. For France and China, the circumstances are less clear-cut. The French program was at least ambiguous in its early years—enough so that many of the scientists involved believed it had only civilian purposes.[16] China's nuclear weapons program was built on a technological foundation established with the help of the Soviet Union, which in 1957 initiated a program of nuclear-technology assistance to its less developed neighbor. Presumably the Soviets were motivated by the idea that China would use this technology for the production of electric power. But the Soviets terminated their assistance a few years later, probably upon becoming convinced that the Chinese were bent on making bombs instead of electricity.[17]

The last confirmed addition to the nuclear-weapons "club" came with the announcement, in 1974, of India's "peaceful" nuclear explosion. The plutonium apparently had come from a research reactor provided by Canada, using heavy water supplied in part by the United States. That the source of the nuclear material was not a *power* reactor is scant consolation; it is hard to believe that Canada and the United States would have provided a research reactor, heavy water and other nuclear assistance to India for any reason other than to facilitate the development of commercial nuclear power.

As Roberta Wohlstetter has argued, the Indian case is a compelling example of the "attractive nuisance" and "cover" syndromes that more complacent observers continue to find either "farfetched" or "adequately precluded."[18] She writes:

> "Policy must principally address. . . the countries that can drift toward a military capability without any intention of arriving at it, and yet that may adopt a civilian program that ultimately places them within days of acquiring material for nuclear explosives. The Indian experience illuminates that process of drifting toward a bomb. Canadian and U.S. help—transfers of facilities, equipment and material, advisory scientific and engineering services, training of Indian personnel, financial subsidies and loans—formed a major ingredient of the Indian program that was shortening critical time to make an explosive. And this help was given before and after the Indians revealed a strong interest in nuclear explosives."[19]

Two additional countries, Israel and South Africa, are not officially nuclear weapons states but are widely suspected of either possessing nuclear

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bombs or being very close to it. The presumed source of Israel's weapons material is a research reactor provided by France—again, not a power reactor but nonetheless a transfer of nuclear technology surely motivated on the supplier's part by a desire to help the recipient develop commercial nuclear power. In South Africa's case, the most likely source of bomb material is highly enriched uranium obtained from technology developed with considerable help from West Germany.

Prospects for further proliferation. The other countries on most lists of potential proliferators—Pakistan, Argentina, Iraq, Libya, Taiwan, South Korea, Brazil—all have achieved this threatening status with the help of technology transferred to promote civilian nuclear power.

Pakistan may test a nuclear bomb within the year.[20] One likely source of the needed nuclear-explosive material is a centrifuge technology for uranium enrichment obtained with considerable inadvertent assistance from Europe. A young Pakistani scientist working in the Netherlands for a subcontractor to a German-British-Dutch commercial enrichment concern returned home with complete plans, specifications and a list of suppliers for an advanced enrichment plant. Pakistan's other potential route to a bomb would use plutonium produced in its CANDU reactor which, along with fuel, was supplied by Canada.

Argentina has power reactors from West Germany and Canada, plus a heavy-water plant from Switzerland. The chairman of the Argentine Atomic Energy Commission has stated publicly that its technologists are able to construct nuclear bombs.[21] Neither Argentina nor Pakistan has ratified the Non-Proliferation Treaty.

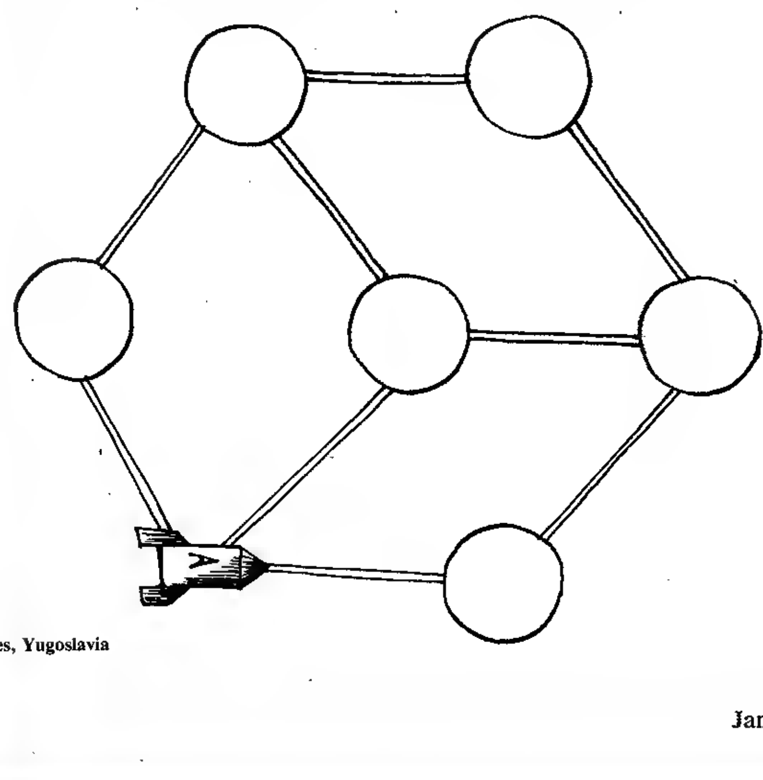
Libya has ratified the Treaty, but that country's obvious pursuit of nuclear weapons indicates how hollow such a commitment can be. With little apparent economic rationale for nuclear-generated electricity, Libya has the largest per capita enrollment of nuclear engineering students in foreign universities of any country in the world.[22] Such training, of course, is as meaningful a transfer of nuclear technology as the shipment of a reactor.

One could continue down the gloomy list, but these examples make the point. If the link between nuclear power and the spread of nuclear weapons is now called "tenuous" by some, it is only because nuclear power *already* has spread the technological base of nuclear weaponry so widely that little further harm seems possible.

Can anything be done? The situation is indeed bad, but it could get worse. And this means both that the link between nuclear power and proliferation must still be considered dangerous, and that it is worth thinking about ways to diminish the danger.

It is true that the basic technical knowledge needed to develop nuclear weapons is already very widespread, and that there are ways, other than the further development of commercial nuclear power, for countries to use that knowledge to acquire nuclear weapons if they want them badly enough. On the other side of the coin: far more nations have *not* yet decided to acquire nuclear bombs than have decided to do so; far more countries have small-to-nonexistent nuclear power programs than have extensive ones; and the extent to which nuclear power programs lower the barriers opposing the acquisition of weapons increases with the scale of the particular programs.

Thus, the further spread and expansion of nuclear power can make things very much worse than they already are. And, under some circumstances, this could mean a flood, rather than a trickle, of entrants into weapon-producing status. One has only to ponder the potential for regional "domino effects"—or to consider the possible reactions of countries such as Japan and West Germany to perceived threats from lesser powers that have



Szeles, Yugoslavia

The presumed source of Israel's weapons material is a research reactor provided by France.

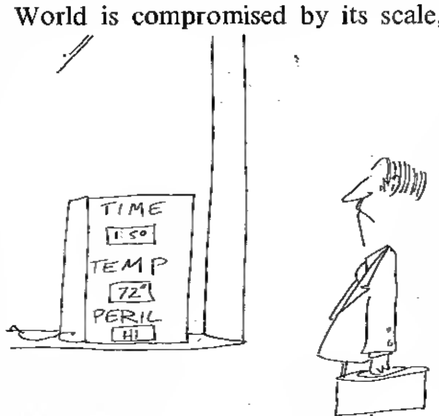
acquired nuclear weapons—to begin to appreciate the possibilities.[23]

What can be done to reduce the danger? Six approaches, not all mutually exclusive, suggest themselves:

- Work to strengthen gradually the Non-Proliferation Treaty and the safeguards, administered under the Treaty by the International Atomic Energy Agency, against weapons use of civilian nuclear technology. This includes efforts to get the major weapons states to meet Treaty obligations calling for good-faith negotiations toward nuclear disarmament.
- Strengthen superpower guarantees against nuclear threats to the security of non-weapons states, in order to reduce the incentives of the latter to acquire their own bombs.
- Seek drastic upgrading of the Treaty and international safeguards, including, for example, internationalization of regional enrichment and reprocessing facilities.
- Attempt to develop and promote more proliferation-resistant fuel cycles for nuclear power generation.
- Take unilateral U.S. action—and, where possible, multilateral action with other nuclear-technology suppliers—to restrict access to proliferation-prone technologies and to punish proliferative action by withholding assistance and by other economic and political sanctions.
- Develop and encourage the world-wide use of a variety of non-nuclear energy options. Some analysts believe that this approach should include *increased* use of nuclear power in the major weapons states, in order to make oil and gas available for use elsewhere and to provide some leeway against the global buildup of atmospheric carbon dioxide from fossil-fuel combustion. Others hold that de-emphasis of fission in weapons states is essential, both to make resources available for the alternatives and to set an example.

Detailed expositions of the pros and cons of these approaches are available elsewhere.[24] Here, I shall emphasize only two points:

- None of the first five approaches is even close to being fully satisfactory. They all have costs, risks and holes. This verdict holds as much for the politically- as for the technologically-oriented ideas. While various combinations of these measures could be tried, the overwhelming likelihood is that even the best attainable results will not prevent *some* acceleration of the spread of nuclear weaponry as a consequence of the spread of nuclear power. This probable contribution to proliferation must be counted a significant cost of nuclear power. Hence it is important to pursue vigorously the sixth approach—the promotion of energy alternatives to fission. This approach is not cheap or easy; but I believe its potential for diminishing further the grave hazards of weapons proliferation outweighs its costs and difficulties.
- The attractions of nuclear energy for industrial and less developed countries alike, *aside* from its proliferation liability, are widely overestimated. This overstatement of fission power's benefits leads in turn to overstating the inevitability of its continuing spread. In fact, however, nuclear energy's usefulness to the Third World is compromised by its scale, degree of centralization, and present restriction to electricity as the delivered energy form. The most compelling energy needs in many of these countries are small in scale, dispersed, remote from electricity grids, and most readily served by portable fuels.



Cline, United States

In industrial nations and in the industrial sectors of the poorer nations, nuclear power is much less able to replace oil —the scarcest and most politically troublesome conventional energy source—than is commonly supposed. This is because in most countries, oil is not used so much to generate electricity as for other purposes. The proposal that the world should turn to nuclear power to help prevent a war over oil is thus undermined by an unfortunate irony: While nuclear power is arguably the fastest, cheapest and politically safest way for a country that has it to acquire a nuclear arsenal, it is probably the slowest, most expensive and least effective.

A race against time. With a lowering of the barriers, the proliferation of nuclear power can hardly fail to boost some countries over the nuclear weapon threshold. But they might never have joined the nuclear-weapons "club" had they not been assisted in acquiring the technology for nuclear power. Others, of course, might have developed nuclear weapons programs from scratch.

But "direct" routes to weapons, apart from civilian power programs, should not greatly lessen our concern about the danger of power-linked proliferation. The hazard of nuclear power is precisely that it will *speed up* the spread of nuclear weaponry. I believe, in this connection, that the only way to view the proliferation problem with any degree of hope is as a race: The race is between the growth of the chance of nuclear war, as some function of the number of countries having the means for it, and the reduction

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of the chance of nuclear war, through increased rationality in world politics.

The way we handle nuclear power in particular, and our energy affairs in general, can at best buy time against the proliferation of nuclear weapons. But that time may make all the difference. ☐

1. Spurgeon M. Keeny, Jr., Seymour Abrahamson, Harold Brown, Albert Carnesale, Abram Chayes, Hollis B. Chenery, Paul Doty, Philip J. Farley, Richard L. Garwin, Marvin L. Goldberger, Carl Kaysen, Hans H. Landsberg, Gordon J. MacDonald, Joseph S. Nye, Wolfgang K.H. Panofsky, Howard Raiffa, George W. Rathjens, John C. Sawhill, Thomas C. Schelling and Arthur Upton, *Nuclear Power Issues and Choices*, Report of the Nuclear Energy Policy Study Group (Cambridge, Massachusetts: Ballinger, 1977), p. 271.

2. Brian Flowers, chairman, *Nuclear Power and the Environment*, Sixth Report of the Royal Commission of Environmental Pollution (London: Her Majesty's Stationery Office, Sept. 1976), p. 76.

3. R. W. Fox, G.G. Kelleher, and C.B. Kerr, *Ranger Uranium Environmental Inquiry: First Report* (Canberra: Australian Government Publishing Office, 1976), p. 178.

4. See Bernard Spinrad, "Nuclear Power and Nuclear Weapons: The Connection is Tenuous," in Jack Hollander, ed., *Nuclear Energy Weapons Proliferation, and the Arms Race* (Stony Brook, New York: American Association of Physics Teachers, 1982), pp. 1-12.

5. Theodore B. Taylor, "Nuclear Safeguards," *Annual Review of Nuclear Science* (1976), pp. 407-21.

6. But see John P. Holdren, "Fusion Power and Nuclear Weapons: A Significant Link?," *Bulletin* (March 1978), pp. 4-5.

7. This conclusion has been expressed in the open literature by analysts with impeccable credentials. See Theodore B. Taylor, "Nuclear Safeguards"; Office of Technology Assessment, U.S. Congress, *Nuclear Proliferation and Safeguards* (New York: Praeger, 1977); Victor Gilinsky, "Plutonium, Proliferation, and Policy," *Technology Review* (Feb. 1977), pp. 58-65. Gilinsky, formerly head of the Physical Science Department at RAND Corporation and Assistant Director for Policy and Program Review of the U.S. Atomic Energy Commission, and now Commissioner at the U.S. Nuclear Regulatory Commission, stated that "reactor-grade plutonium may be used for nuclear warheads at all levels of technical sophistication. . . . Countries less advanced than the major industrial powers . . . can make very respectable nuclear weapons," p. 61.

8. Spurgeon M. Keeny and others, *Nuclear Power*, p. 280. A third flaw in the complacent view of "reactor-grade" plutonium will materialize if laser isotope separation becomes an inexpensive way to get rid of the unwanted isotopes in plutonium from light-water reactors.

9. Bernard Spinrad, "Nuclear Power."

10. Theodore B. Taylor, *Nuclear Proliferation*; John R. Lamarsh, "On Construction of Plutonium-Producing Reactors by Small and/or Developing Nations" *Nuclear Proliferation Factbook* (Washington, D.C.: Government Printing Office, 1977), pp. 533-62.

11. Colin Norman, "Weapons Builders Eye Civilian Reactor Fuel," *Science*, 214, Oct. 16, 1981, pp. 307-08.

12. Ted Greenwood, Harold A. Feiveson, Theodore B. Taylor, *Nuclear Proliferation* (New York: McGraw-Hill, 1977); Keeny and others, *Nuclear Power*.

13. In some circumstances a country may find its interests better served by ambiguity about its nuclear-weapons status than by acknowledgment of possession. See Victor Gilinsky, "Diversion by National Governments," in Mason Willrich, ed., *International Safeguards and Nuclear Industry* (Baltimore: Johns Hopkins Press, 1973), pp. 159-75.

14. Victor Gilinsky, "Nuclear Energy and the Proliferation of Nuclear Weapons," in Albert Wohlstetter, Victor Gilinsky, Robert Gillette, Roberta Wohlstetter, *Nuclear Policies: Fuel Without the Bomb* (Cambridge, Massachusetts: Ballinger, 1978), p. 89.

15. Spinrad, "Nuclear Power"; Keeny and others, *Nuclear Power*, p. 280.

16. Lawrence Scheinman, *Atomic Energy Policy in France Under the Fourth Republic* (Princeton: Princeton University Press, 1965).

17. Office of Technology Assessment, *Nuclear Proliferation*.

18. Spinrad, "Nuclear Power."

19. Roberta Wohlstetter, "U.S. Peaceful Aid and the Indian Bomb," in Albert Wohlstetter and others, *Nuclear Policies*.

20. David K. Willis, "On the Trail of the A-Bomb Makers," *The Christian Science Monitor*, Nov. 30-Dec. 4, 1981.

21. Office of Technology Assessment, *Nuclear Proliferation*.

22. David K. Willis, "On the Trail."

23. J. K. King, ed., *International Political Effects of the Spread of Nuclear Weapons* (Washington D.C.: Government Printing Office, April 1979).

24. See especially Gene I. Rochlin, *Plutonium, Power, and Politics* (Berkeley: University of California Press, 1979); Amory B. Lovins, L. Hunter Lovins, Leonard Ross, "Nuclear Power and Nuclear Bombs," *Foreign Affairs*, Summer 1980; Keeny, *Nuclear Power*; Greenwood, Feiveson and Taylor, *Nuclear Proliferation*; Wohlstetter, Gilinsky, Gillette, Wohlstetter, *Nuclear Policies*.

A version of Bernard Spinrad's article "Nuclear Power and Nuclear Weapons: The Connection is Tenuous" (see footnote 4) will appear in the February issue of the ***Bulletin***.